The spider's web

Complexity simplified

Most biologists both love and hate the complexity of biological systems. A complex system is a dynamic system that behaves in a non-linear fashion and is composed of many interacting elements — a definition that easily covers biomolecules, cells, tissues, organisms and groups of organisms. Emergent behaviors (that is, global behaviors that arise, but are not easily predicted, from the simple interactions of the individual components) are their hallmark.

The development of powerful computational and mathematical tools promises to revolutionize the way scientists study the complexity of biological systems, but you don't have to be a mathematician to make use of these tools. There are some excellent online resources on complex systems for beginners, and of course for complexity experts. Although few web sites are specific to complexity in biology, many multidisciplinary web sites include examples of complexity research as applied to biological systems.

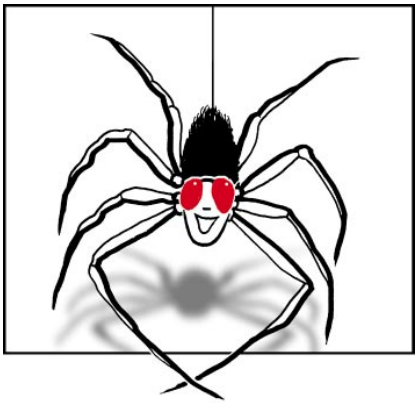
Building tools that will help beginners understand complex systems is one of the main goals of the Connected Mathematics project (Making Sense of Complex Phenomena Through Building Object-Based Parallel Models) based at Tufts University. The project has one of the best educational web sites on complex systems and a highlight is a library of downloadable connected models — which users can manipulate and extend — that simulate the behavior of complex systems.

Another educational project at the University of Georgia aims to find out how people can learn the fundamental concepts of complex systems. The Cognition, Technology and Complex Systems web site provides a list of books, including several didactic books for beginners, and a good glossary.

A site with excellent explanations for both basic and advanced concepts in complexity is the FAQs document from the Usenet newsgroup sci.nonlinear. Put together by Jim Meiss at the University of Colorado at Boulder, this document not only features clear explanations in its Basic Theory and Applications and Advanced Theory sections, but also maintains a large and well-organized list of web sites and a bibliography that includes popular-science, basic and advanced texts.

A network of servers coordinated by the Charles Sturt University in Australia, Complexity On-line, provides the most comprehensive online service for information on complex systems. Of particular interest is the Complex Systems Virtual Library but other valuable resources include a list of newsgroups, a searchable bibliographic database and a software repository.

The Santa Fe Institute is one of the hubs of research on complex systems, with projects ranging from the patterns of communication between ants to the spread of information across economic markets. Two sites maintained by the Santa Fe Institute are particularly worth visiting. The first details the Evolving Cellular Automata Project, which aims to understand how evolution produces sophisticated properties in systems composed of simple elements that are limited to local interactions.



Artificial life — another way of looking at biological behaviors using computers and other artificial media — is described at the up-to-date Santa Fe Institute site Alife Online, which includes FAQs, general descriptions of many topics in Alife, outstanding lists of web links and software, search functions and details of conferences and courses.

The refereed web journal *InterJournal* is produced by the New England Complex Systems Institute. Although the journal specializes in three main subjects — Complex Systems, Genetics and Polymers and Complex fluids — the vast majority of articles fall into the Complex Systems category. The journal makes innovative use of its electronic format, accepting data for publication in a wide range of formats.

The study of complex systems might seem arcane at first glance, but the next time you find yourself trying to understand why the inhibitor of the activator of the kinase pathway that converges with several of your favorite receptor-activated pathways is turned off, rather than on as predicted, a look on the web might help to simplify matters.

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This month's URLs

Connected Mathematics project	http://www.ccl.tufts.edu/cm/
Cognition, Technology and Complex Systems Group	http://lpsl.coe.uga.edu/Jacobson/ctcs/
sci.nonlinear FAQ	http://amath.colorado.edu/appm/faculty/jdm/faq.html
Complexity On-line	http://complex.csu.edu.au/complex/
Santa Fe Institute	http://www.santafe.edu/
Evolving Cellular Automata Project	http://www.santafe.edu/projects/evca/
Alife Online	http://alife.santafe.edu/
InterJournal	http://interjournal.org/
New England Complex Systems Institute	http://www.necsi.org/html/research.html